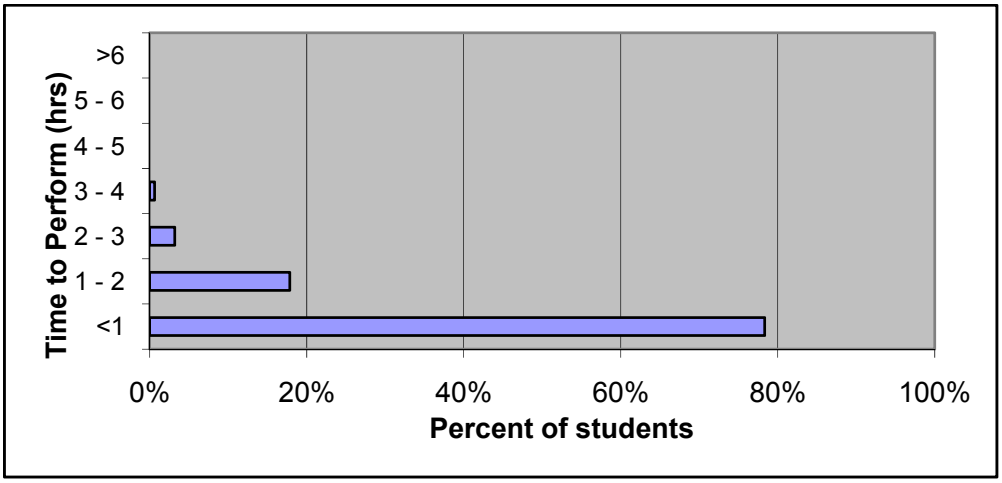
Experiment 1: Breadboard Basics

Developers KM Lai, JB Webb, and RW Hendricks

Objectives The objective of this experiment is to measure and to draw the electrical connections within the ANDY board breadboard.

Estimated Time for Completion



Preparation Read the general descriptions of the ANDY board and the digital multimeter given in Sections 3.3 and 3.5 of this text, respectively. Also read the ANDY Board User Manual and Test Procedure and be sure that you have performed the entire acceptance test procedure as described therein. Finally, read the hand-held DMM operator's manual that came with the MY-64 DMM. If you are using some other DMM, read the users' manual that accompanied it.

Background With the exception of Experiment 2, all of the experiments described in this book will be built on a platform called a breadboard. The breadboard consists of a series of holes behind which are spring contacts that make electrical connection with wires that are inserted into the holes. These springs are connected together in various combinations to create electrical nodes. All the wires connected to springs that are connected together will be at the same potential. In this experiment, you will experimentally determine which holes are connected together to create electrical nodes for the breadboard associated with your lab kit. Although breadboards are manufactured by many firms, there is some consistency between them. However, there are also some very important differences. Thus, it is imperative that you verify for yourself how your particular breadboard is wired. Depending on the lab kit provided for your experiments, this breadboard may be stand-alone (unpowered) in which you will use batteries to provide a source of DC power, all the way to fully powered lab "trainer kits" such as the ANDY board in which various voltage sources, clocks, and/or function generators may be provided. Regardless of these additional features, the breadboard remains essentially independent of them.

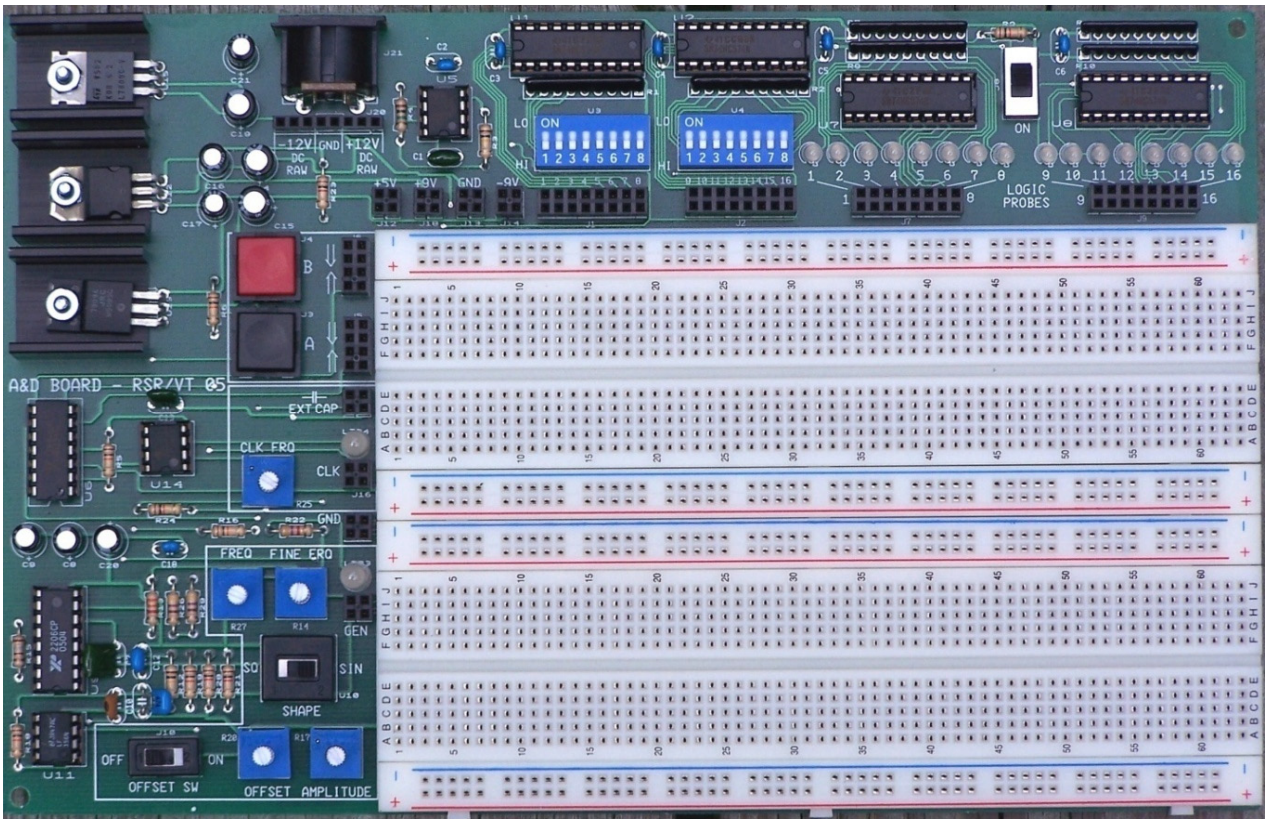


Figure 1: The RSR/VT Analog and Digital ANDY Trainer

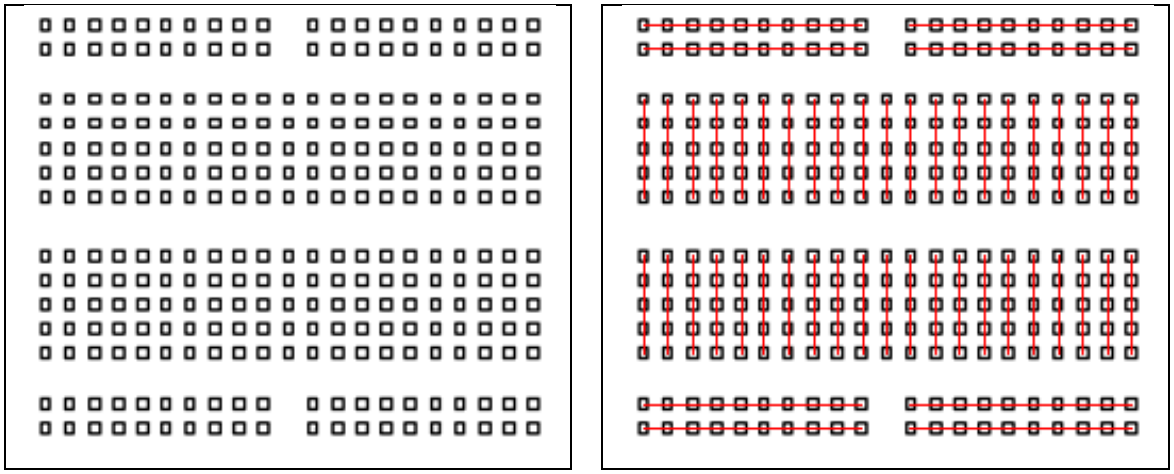
Breadboard Construction

There is a great variety of breadboards, each having a different number of columns and with different numbers of vertically connected holes (usually five or six.). Some have single troughs in the middle of the board and some have two troughs. Some boards have all of the holes in the outer two rows connected and some have a break in the connection in the middle. The student needs to be aware of these many variations and needs to be able to quickly determine how the board she is using is connected internally. A typical breadboard will look similar to the picture shown in Figure 1. Note that the RSR/VT ANDY trainer shown in Figure 1 has two identical breadboards—an upper board and a lower board.

Figure 2(a) shows the layout of a segment of a typical breadboard while Figure 2(b) shows the wiring diagram of its backplane. In both figures, the top two horizontal rows and the bottom two horizontal rows of the breadboard are typically used for power busses and ground busses. A bus is simply a node with multiple connection points all of which are at the same electrical potential or voltage. These busses are clearly marked in Figure 1 with a red "+" and a blue "-" on each end of the row and with long horizontal red and blue lines. The rows on the breadboards in Figure 1 are labeled with letters $(\mathrm{A}, \mathrm{B}, \mathrm{C}, \cdots)$ while the columns are numbered $(1, 5, 10, \cdots)$ thus allowing specific identification of each node. Other boards may be marked differently or may be unmarked.

Notice that the breaks in the busses in Figures 1 and 2 differ. In Figure 1 there is a break every five holes while in Figure 2 there is a break only in the middle of the board. Figure 2(b) indicates that there is a break in the wiring between the two sides of the board, while the blue and red horizontal lines might imply that there is no such break in the wiring in Figure 1. Thus, you must determine experimentally if there is or is not a connection between the breaks on the ANDY board. If there is no electrical connection between the two sides you must remember to use a jumper wire to connect them if you desire to have a bus that runs the entire width of the board. (See, e.g., Figures 9 and 10.)

The vertical columns of holes are also busses and are typically used for inserting devices and wires. Notice the horizontal break or trough in the vertical columns in the middle of the breadboard. In Figure 2 there is no electrical connection between the upper and lower halves. The break in the vertical columns has a special purpose. It provides a convenient place for inserting integrated circuit chips into the breadboard. The hole spacing between the upper and lower rows on each side of the trough is exactly the pin spacing of the dual inline pins (DIP) of the chips used in the experiments. By placing a chip so that it straddles the trough between the upper and lower halves, the pins on the opposite sides of the chip are isolated from each other. In placing chips and other components on the breadboard, it is imperative to be sure that each pin on the device is in a separate column, otherwise they will be shorted together. Connections between columns must be made by the designer using wires on the component side of the board.



(a) (b)

Figure 2: Typical breadboard (a) socket layout, and (b) socket interconnections.

References

Lineberry, R.B., W.C. Headley, and R.W. Hendricks, (2006). "RSR/VT ANDY Board User Manual and Test Procedure." The Bradley Department of Electrical and Computer Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061 (Available at **http://www.lab-in-a-box.net**)

Materials

The equipment and components required to perform this experiment are:

- ANDY board
- Digital multimeter
- Wire
- Wire strippers

Procedure

Following the concepts of Figure 3, verify the electrical connections in the breadboard. Be sure to orient your breadboard in the same way as the picture. To measure resistance, insert the red DMM test lead into the red jack on the DMM labeled with 'V', 'Ω', and 'Hz'. Turn the DMM knob to the setting marked with the 'Ω' symbol. Put the resistance setting on the lowest scale. If the multimeter registers an overflow, write overflow (see Section 3.5 for a discussion of the DMM overflow). You are trying to verify the connections in the breadboard as shown (typically) in the diagram. It is not critical which holes you measure so long as you measure holes as typically shown in Figure 3. For busses, you will get a low resistance (typically about an ohm). For non-connected input points, points not in a bus or on the same node, you will get an overflow.

Notes:

1. The pointed tips on the DMM test leads are too large for the holes in the breadboard. If you try to force the tip into the hole, you may stretch the contact spring beyond its elastic limit and thus ruin the spring. To avoid this, cut and strip two short pieces of wire from your wire spool. Insert the wires into the breadboard at the desired locations (see below) and then touch your DMM test leads to the wire ends.
2. **Do not plug in the power supply for your breadboard** while performing this experiment.

1. Measure the resistance within one row in the power bus. This is (typically) from points 1 to 2 in Figure 3.
2. Measure the resistance between vertically separated rows of power busses. This is (typically) from points 1 to 3 in Figure 3.
3. Measure the resistance between horizontally separated rows in the power busses. This is (typically) from points 2 to 4 in Figure 3. How are the power busses in the ANDY board wired?

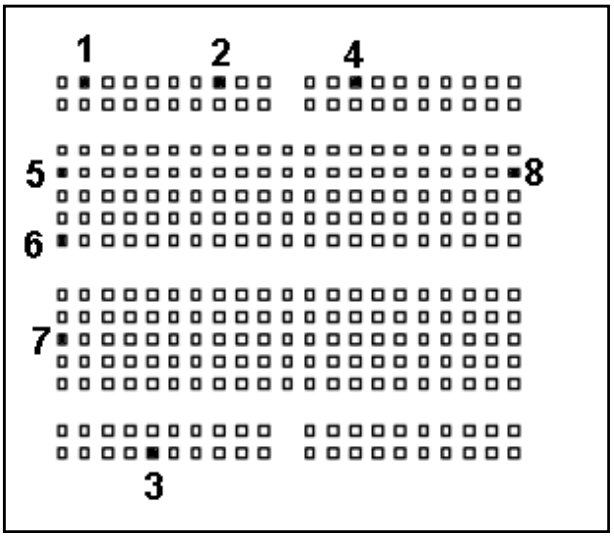


Figure 3: Breadboard measurement locations.

4. Measure the resistance within one column of the device working area. This is (typically) from points 5 to 6 in Figure 3.
5. Measure the resistance between nodes in the same column, but which are separated by the horizontal channel. This is (typically) from points 6 to 7 in Figure 3.
6. Measure the resistance between horizontally separated columns in the working area. This is (typically) from points 5 to 8 in Figure 3.
7. Measure the resistance between rows and columns (i.e., between the power busses and the columns in the working area.) This is (typically) from points 1 to 5 in Figure 3.
8. Prepare a drawing of your breadboard and mark the back plane connections as is illustrated in Figure 2(b). Your drawing need not be to scale. However, it should show all of the rows of the board but only a sufficient number of columns to be representative.
9. For future reference, save a copy of your drawing with your lab kit.

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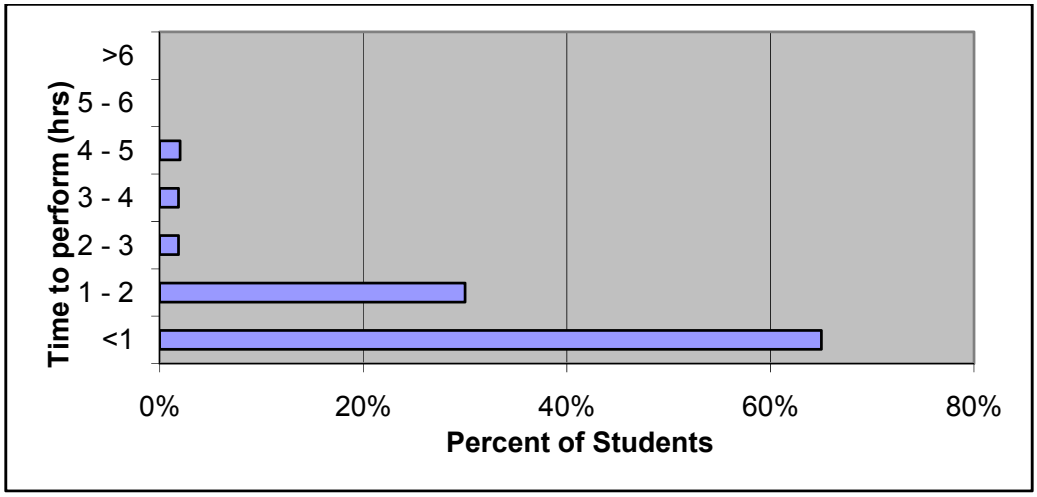
Experiment 3: Ohm's Law

Developers JB Webb, KM Lai and RW Hendricks

Objectives The objective of this experiment is to verify Ohm's law.

Estimated Time for Completion



Preparation Read the section on Ohm's law in your textbook. Also read Sections 2.3 (Analysis of Data), Appendix C, 3.3 (RSR/VT ANDY Board), 3.4 (Breadboarding and Wiring), 3.5 (Multimeter), and 3.8 (Resistors) of this book.

Background Ohm's law states the relationship between the voltage (V, in volts) across a resistor and the current (I, in amperes) through that resistor is:

$$V = I R \tag{1}$$

where R is the resistance (in ohms). This linear relationship is an approximation that has proven to be adequate for most work in electric circuit analysis. You will learn in more advanced courses that the relationship is not truly linear, but that depending on how and from what the resistor is made, the resistance may vary with applied voltage and magnetic field. There is also a significant change in resistance with temperature. These effects are discussed in most solid state physics texts such as Hook and Hall (1995). PSpice allows for corrections for the temperature dependence and other effects.

In this experiment you will verify Ohm's law by measuring the current through a resistor as a function of the applied voltage and will verify that the measured value of the resistor is within its specified tolerance. Note that all resistors provided with Lab-in-a-Box have a 5% tolerance, meaning that each resistor is within 5% of its nominal, or color-coded value.

References

Hook, J.R., and H.E. Hall, (1995). Introduction to Solid State Physics (8/E). New York: John Wiley & Sons.

Materials

The equipment and components required to perform this experiment are:

- ANDY Board
- Digital multimeter
- 1 ea 1000 Ω resistor (Brown Black Red Gold)
- 1 ea mystery resistor (Red Black Brown Gold). This resistor will be found in the bag of course-specific parts.

Procedure

Consider the circuit diagram shown in Figure 1. A voltage of 9V is applied to a series connection of the unknown resistor and a 1 kΩ resistor.

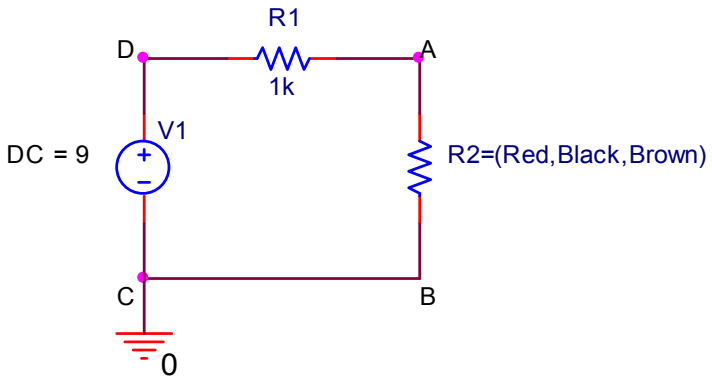


Figure 1: Circuit for verifying Ohm's law.

Analysis:

1. Identify the unknown resistor R_2 shown in Figure 1. What value does the color scheme "Red Black Brown" stand for?
2. Calculate the current I_{AB} flowing through the unknown resistor and the voltage V_{AB} across it.
3. What is the purpose of the 1 kΩ resistor?

Measurements:

4. Construct the circuit shown in Figure 1 on your breadboard. Note that the 9 V source is provided by the ANDY board.
5. Plug the black DMM probe into COM and the red probe into V. Set the switch to the lowest volts scale that will not overflow for the expected voltage.
6. Measure the voltage V_{AB} across the unknown resistor. (See Section 3.5 for good technique.) Make sure your polarities are correct. Be sure to include your units!
7. Disconnect the wire from the unknown resistor to ground (wire BC).

8. Move the red DMM probe from the "V" jack to the "mA" jack and set the DMM switch to the minimum full-scale current value that will not overflow for the expected current calculated in step 2.
9. Measure the current I_{BC} passing ***through*** the resistor by completing the circuit with the two DMM probes. To do this, place the red probe on node B and the black probe on node C. Review Section 3.5 for the proper technique for measuring current. Again, make sure your polarities are correct.
10. Using Ohm's law, find the resistance value of the unknown resistor.

$$R_{\text{expt}} = \frac{V_{\text{meas}}}{I_{\text{meas}}} \tag{2}$$

11. Remove the resistor from your circuit.
12. Move the red DMM probe to the "R" jack and measure the resistance of the unknown resistor.
13. What is the percent difference between your experimentally determined resistance in step 10 and the measured resistance value found in step 12?

$$\Delta = \frac{\left|R_{\text{meas}} - R_{\text{expt}}\right|}{\mathrm{R}_{\text{expt}}} \times 100\% \tag{3}$$

14. What is the percent difference between the experimentally determined resistance found in step 10 and the nominal resistance value found in step 1?

$$\Delta = \frac{\left|\mathrm{R}_{\text{nom}} - R_{\text{expt}}\right|}{\mathrm{R}_{\text{nom}}} \times 100\% \tag{4}$$

15. Is the difference of the experimentally determined value in step 10 within 5% of the nominal value? Is the difference acceptable? Why or why not?

Error Analysis:

16. Following the methodology of the propagation of errors described in Appendix C, estimate the standard error of R_{expt} computed from Eq (2) above. Assume $\sigma_{V_{\text{meas}}}$ and $\sigma_{I_{\text{meas}}}$ are ±1 digit in the least significant digit of the scales used to measure the voltage and the current, respectively.
17. Using your estimate of $\sigma_{R_{\text{expt}}}$ from step 16 and an estimate of $\sigma_{R_{\text{meas}}}$ based on ±1 digit in the least significant digit of the scales used to measure the resistance, perform a t-test as described in Appendix C to determine if your experimental and measured values of the resistance are statistically significantly different from each other at the 95% confidence level. Explain any discrepancies.

18. Following the methodology of Appendix C, perform t-tests to determine if your measured and experimental values of the resistance are statistically significantly different from the nominal value. Are they within the tolerance of the color band on the resistor? Explain.

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